REMARKS

Claims 16-19 and 25 are pending in the application.

Support For Claim Amendments

In claims 16, 17 and 25, the term "bumps" has been deleted to make clear that the present invention is directed to --metal balls--.

Claims 16 and 17 have also been amended to specify that the metal balls --are physically attached to tops of the electrodes--.

This is supported by the phrase --for the attachment of bumps" which has been deleted from claims 16 and 17 by the present amendment. It is also supported in the specification, e.g., at page 4, lines 28-32 and illustrated in Fig. 1 of the drawings.

New matter is not being presented by the present amendment.

§103

Claims 16-18, and 25 were rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 4,940,181 to Juskey, Jr. et al. and U.S. Patent No. 5,773,359 to Mitchell et al.

Claim 19 was rejected under 35 U.S.C. §103(a) as being unpatentable over Juskey, Jr. et al. in view of Japan No. 4-65130 to Okuyama.

These rejections, as applied to the amended claims, are respectfully traversed.

Patentability

The present invention is directed to a process for producing a semiconductor device, the device having metal balls, which are substantially spherical, and are only adhesive bonded to the respective electrodes of the device with flux without reflowing, and are physically attached to the tops of the electrodes. In the process of the present invention, flux is used as an adhesive to bond the metal balls to the tops of the respective electrodes of the semiconductor device.

Juskey, Jr. et al. (US 4,940,181, hereinafter referred to as "Juskey") discloses a method for mounting a member, such as a semiconductor chip or device, onto a substrate. The semiconductor chip or device has solder bumps 30 (Figs. 3 and 4) through which it is mounted to the substrate. Thus, Juskey does not show a semiconductor device having spherical solder balls, but shows only a semiconductor device having bumps. In addition, no process for producing a semiconductor device is referred to in Juskey. Also, using flux as an adhesive for bonding solder balls, which are mobile, in place is neither disclosed nor suggested by Juskey.

The top half of Fig. 3 of Juskey relates to the present invention, i.e., semiconductor chip carrier 28 with solder bump 30. See, e.g., Col. 3, lines 26-34. Fig. 3 illustrates a reflowed solder bump 30 on chip carrier 28.

There is no disclosure or suggestion in Fig. 3 of Juskey of adhesive bonding metal balls to the electrodes of a semiconductor chip with a flux without reflowing the metal balls.

Mitchell et al. (US 5,773,359, hereinafter referred to as "Mitchell") describes forming a bump by a plating process. Mitchell does not disclose or suggest the use of a metal ball or the use of flux.

In a general plating process, a metal bump is formed by the following steps, referring to the drawing of Attachment A hereto:

A. forming a metal pad and a passivation layer on a substrate, such as an IC chip (corresponding to steps 11-13 in Fig. 1 of Mitchell);

B. forming a UBM (Under Bump Metallugy) layer;

C. forming a resist pattern having an opening;

D. filling a bump material in the opening by electroplating;

E. removing the resist pattern;

F. etching the UBM layer using the bump as a mask; and

G. reflowing the bump material to form a semispherical bump.

The differences between the plating process used in Mitchell and the process using metal balls and flux of the present invention are summarized as follows:

(1) In the plating process, such as Mitchell, a bump is formed by reflowing a columnar bump material deposited on an UBM by electroplating. In the process of the present invention, a metal ball, which is formed in a shape of substantially spherical ball in advance, is transferred onto an UBM and is bonded thereto by flux.

(2) In the plating process, since the bump material is deposited on the UBM, the bump formed is in contact with the entire surface of the UBM (see D-G in Attachment A hereto and Fig. 3 of Mitchell). Although Mitchell states that "interconnect bump 29 is similar in shape to a sphere" (column 3, lines 34-35) it is evident that the bump of Mitchell is a semisphere, as illustrated in Figs. 3 and 4, rather than a sphere. In the process of the present invention, the metal ball is in contact with part of the surface of the UBM.

(3) In the plating process, the bump material is deposited on the UBM without using flux. In the process of the present invention, the use of flux is essential.

(4) With the plating process, a choice of alloys of bump material is limited. For example, in the case of solder materials, it is a global trend to use a Pb-free solder material, such as a ternary alloy of a type of Sn-Ag-Cu, in consideration of the environment. However, no plating solution for such a ternary alloy is known. In the process of the present invention, which uses a metallic ball material

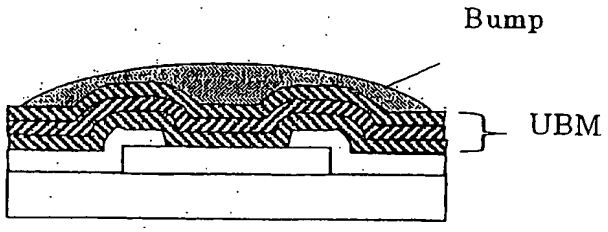
prepared in advance, a choice of materials used is not limited.

(5) In the plating process, bumps formed on a wafer vary greatly in height. For example, in the case of bumps on an 8-inch wafer, they vary in height by about 10 micrometers. In the process of the present invention, metal balls having uniformity of diameter can be used to provide an array of metal balls uniform in their height (the variation in height is within the range of 5 micrometers or smaller).

(6) The plating process uses a mask process, which takes a long time. Further, when relatively large bumps are to be formed, the plating process also takes a long time for the deposition of the bump material (in some cases, 30 to 60 minutes). These reduce the throughput of the process, leading to increased production cost. The process of the present invention does not need a mask process. The throughput of the process of the present invention is not dependent on the size of the balls used, which are prepared in advance. Therefore, the process of the present invention can have a consistent process time (about 5 minutes for ball transfer), and can handle various balls at a low cost.

Further, it should be noted that in Mitchell, the semispherical bump is formed by reflowing the columnar bump material deposited on the UBM layer prior to the etching thereof (see Fig. 2, and column 3, lines 38-43). In such a case where the bump material is reflowed prior to the removal

of UBM layer, the reflowed material wets the UBM layer and spreads thereover, resulting in a flat bump rather than a semispherical bump, as illustrated below. In fact, the process in Mitchell is less practical, and neither discloses nor suggests the process of the present invention.



Consequently, no person with ordinary skill in the art could easily have conceived of the present invention of independent claims 16 and 17 based on each or combination of Juskey and Mitchell.

It is therefore submitted that independent claims 16 and 17, and all claims dependent thereon, are patentable over Juskey and/or Mitchell.

In Okuyama, solder balls 8 for bump formation are fixed to an insulation substrate 2 through pads 6 and flux 23, as seen in Fig. 1, to provide a terminal resistance unit 1 (Fig. 12), in which bumps 4, 5 are formed on the insulation substrate, for the connection with external connecting terminals. Thus, the solder balls in Okuyama are provided on an insulation substrate, and are used for the bonding of resistor elements. The solder balls used in Okuyama have a diameter of 0.3 to 0.4 millimeter (page 2, the lower left column, lines 13 to 15, and the lower right column, lines 6

to 9), which is much larger than the metal balls of independent claims 16 and 17 (less than 0.15mm). The unit as described in Okuyama has a relatively small number of terminals, and the bumps formed thereon are not needed to have a strictly controlled height.

In contrast, the present invention is directed to the bonding of metal balls onto a chip (semiconductor device), as described above. During the mounting of the chip provided with the metal balls, they are used for the internal connection in a semiconductor package. The metal balls have a diameter of 150 micrometers (0.15mm) or smaller. A semiconductor device has a much larger number (in some cases, several thousands) of terminals (bumps) compared to a resistor, which has only two terminals. In such a semiconductor device, it is essential that the balls are formed with a high accuracy to have a strictly controlled height. When a chip having a large number of metal balls formed with a low height accuracy is flip-chip bonded to a substrate such as an interposer, variation in ball height results in defective junctions. Such a strict ball height accuracy is not required for the external connecting terminals in Okuyama. As such, none of the object, constitution, operation, and effect of the present invention is disclosed or suggested in Okuyama. Okuyama is not properly combinable with Juskey.

It is therefore submitted that dependent claim 19 is patentable over Juskey in view of Okuyama.

CONCLUSION

It is submitted that in view of the present amendment and foregoing remarks, the application is now in condition for allowance. It is therefore respectfully requested that the present amendment be entered and the application, as amended, be allowed and passed for issue.

Respectfully submitted,

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